M20 Surface Muon Beam Line

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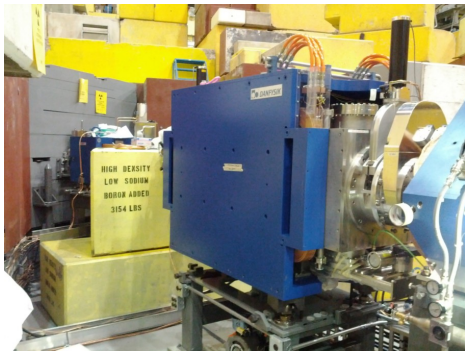
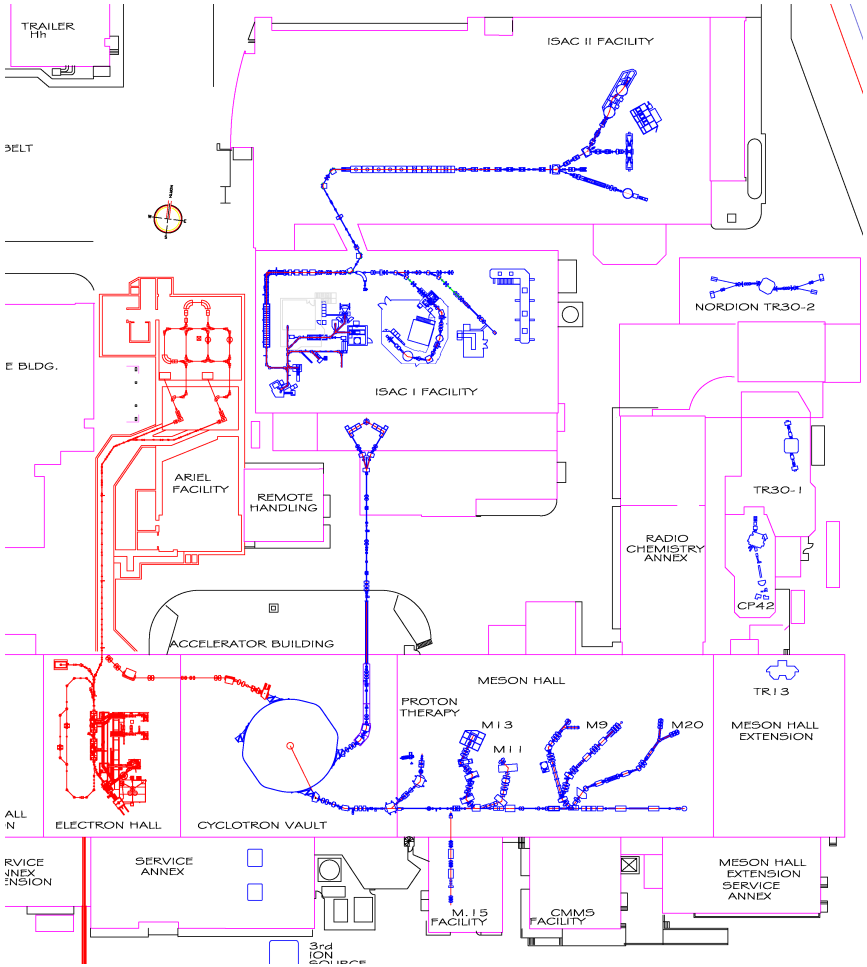
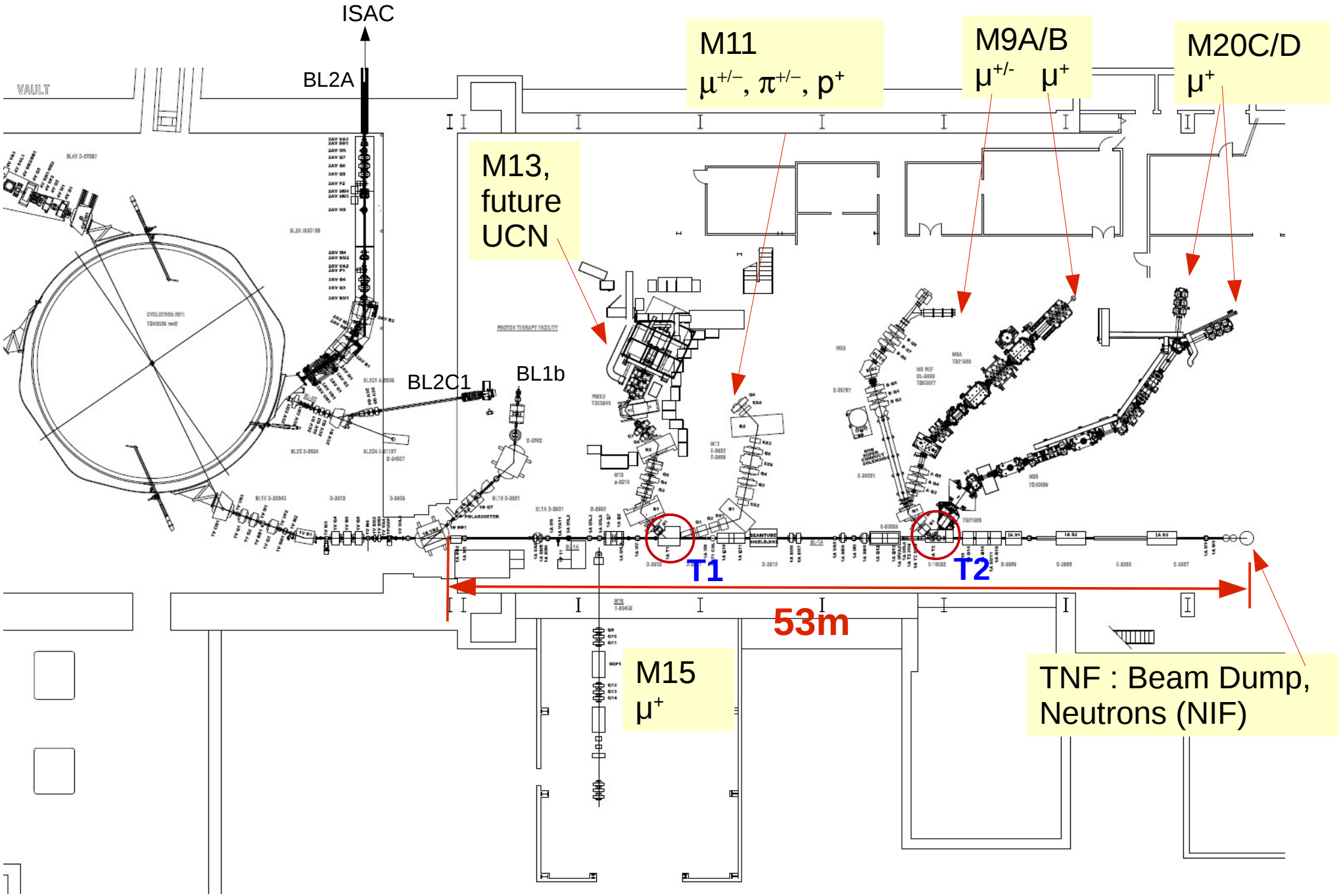


Transformative Hadron BeamLines Workshop - BNL 2014.7.21-23

TRIUMF Meson Hall



Meson Hall - Beamline 1A



Beamline 1A Users

Beamline 1A delivers p^+ at 480 ~ 500MeV, 100-140 μA into the Meson hall to generate :

- 4.2MeV surface muons mostly for the μSR program at M15 (from T1) and M9a, M20 (from T2).

- Energetic μ^+ and μ^- for high pressure μSR and other muon expts at M9b (via T2).

- Beams for detector testing and development at M11 (via T1).

- Neutrons for irradiation studies of electronic devices at TNF.

- isotope production at TNF.

- Neutron production at UCN (formerly M13).

Simultaneous operation of all of these from one proton beam makes BL1A highly productive.

Beamline 1A & Targets

Beamline 1A beam properties :

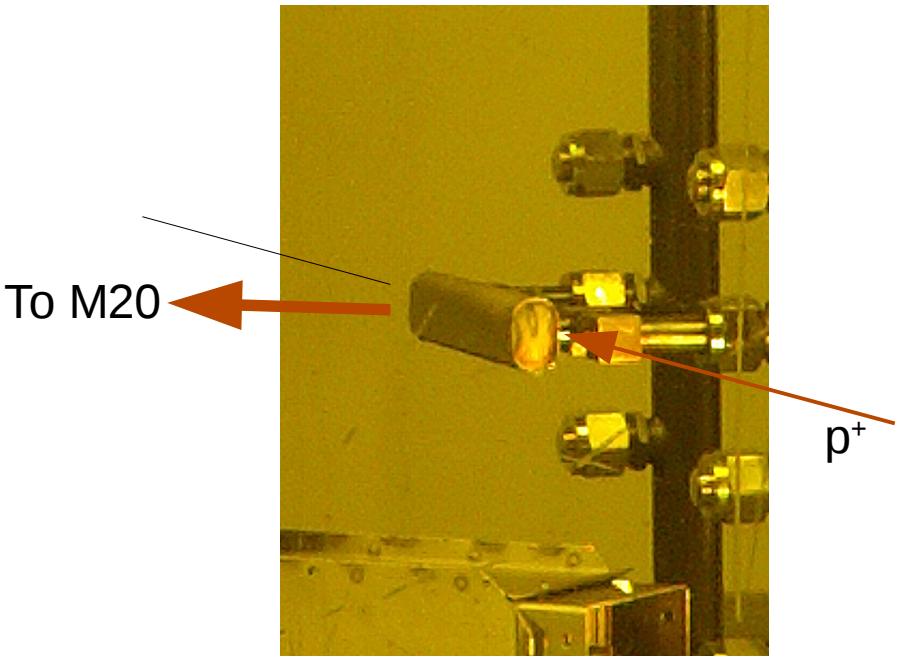
- 480 – 500 MeV p^+
- 110 - 140 μA, depending on simultaneous extraction to other BL's.
- Cyclotron RF : CW @ 23MHz
- Pulse structure : 1kHz, ~95% duty factor

Two production targets:

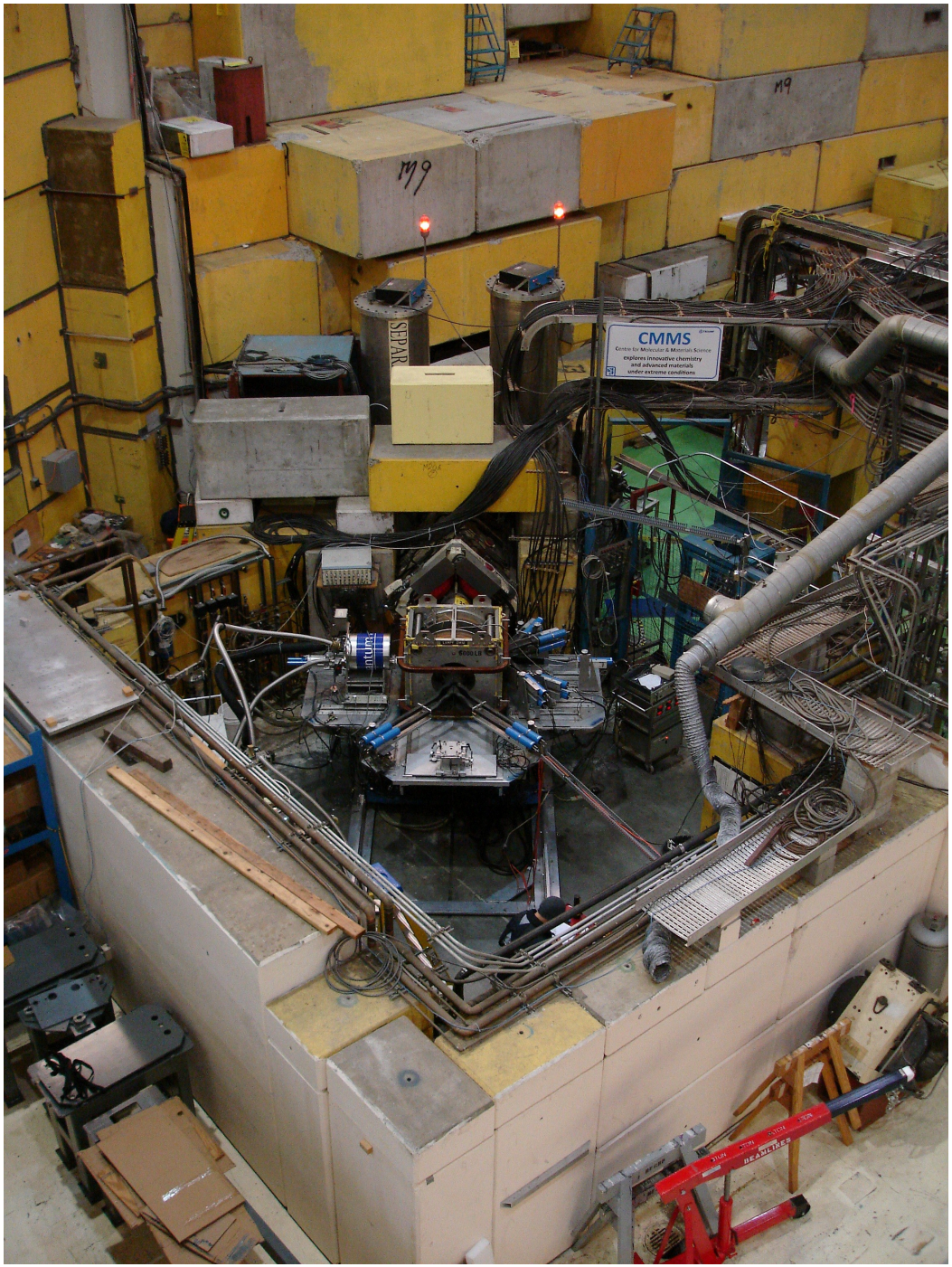
- T1: 1cm Be
  - serves M15 and M11
- T2: 10cm Be
  - serves M9 a/b, M20 c/d

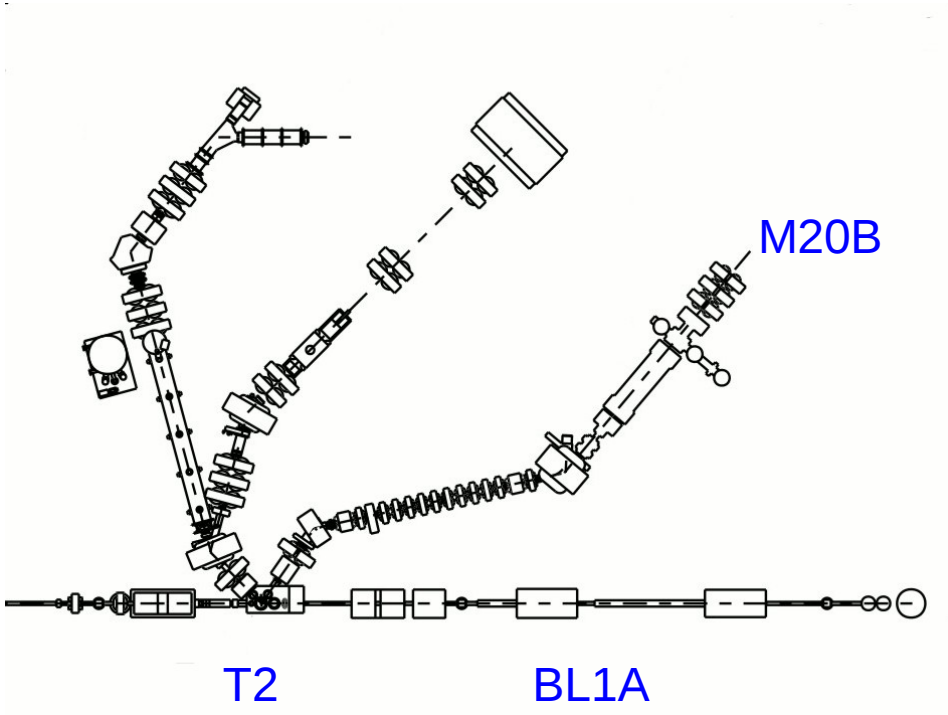
Targets are stationary.

Muon emitting surface is the outside of the water cooling jacket.



The Old M20B



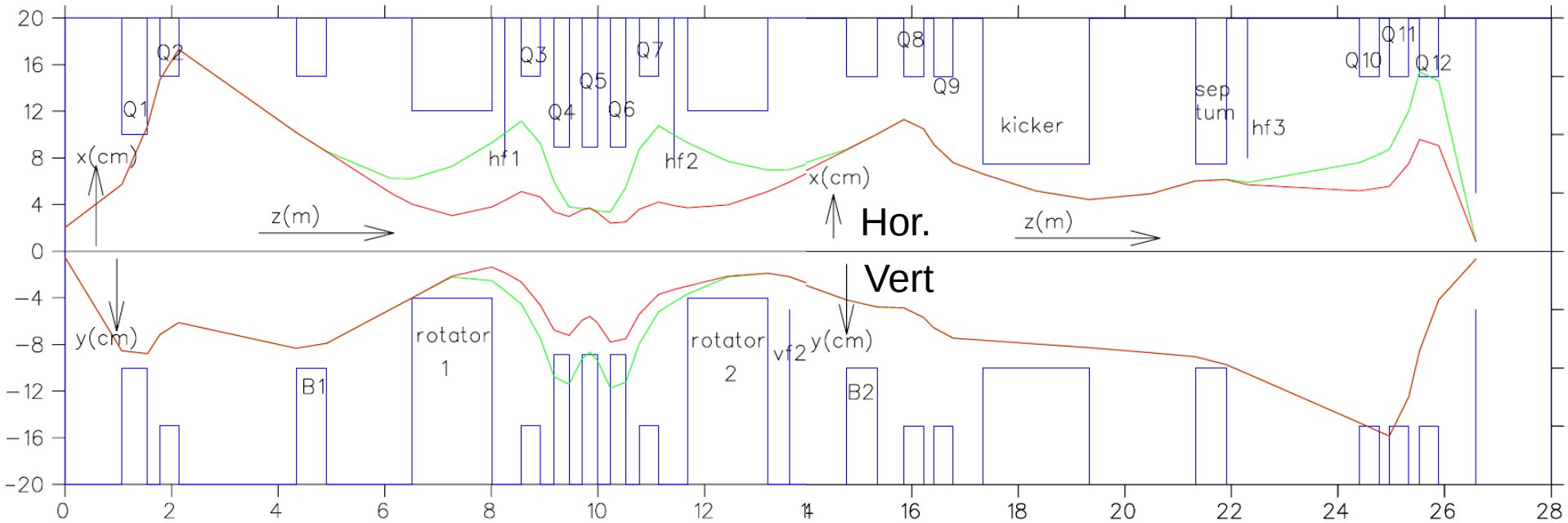


M20B :
Operated 1983 to November 26, 2011

- High flux but a large beam spot.
- One spin rotator / separator.

New M20 optics

Surface μ^+ Beam Envelope



T2

Distance from T2 [m]

Final Focus

Red = +/- 0% ΔP/P

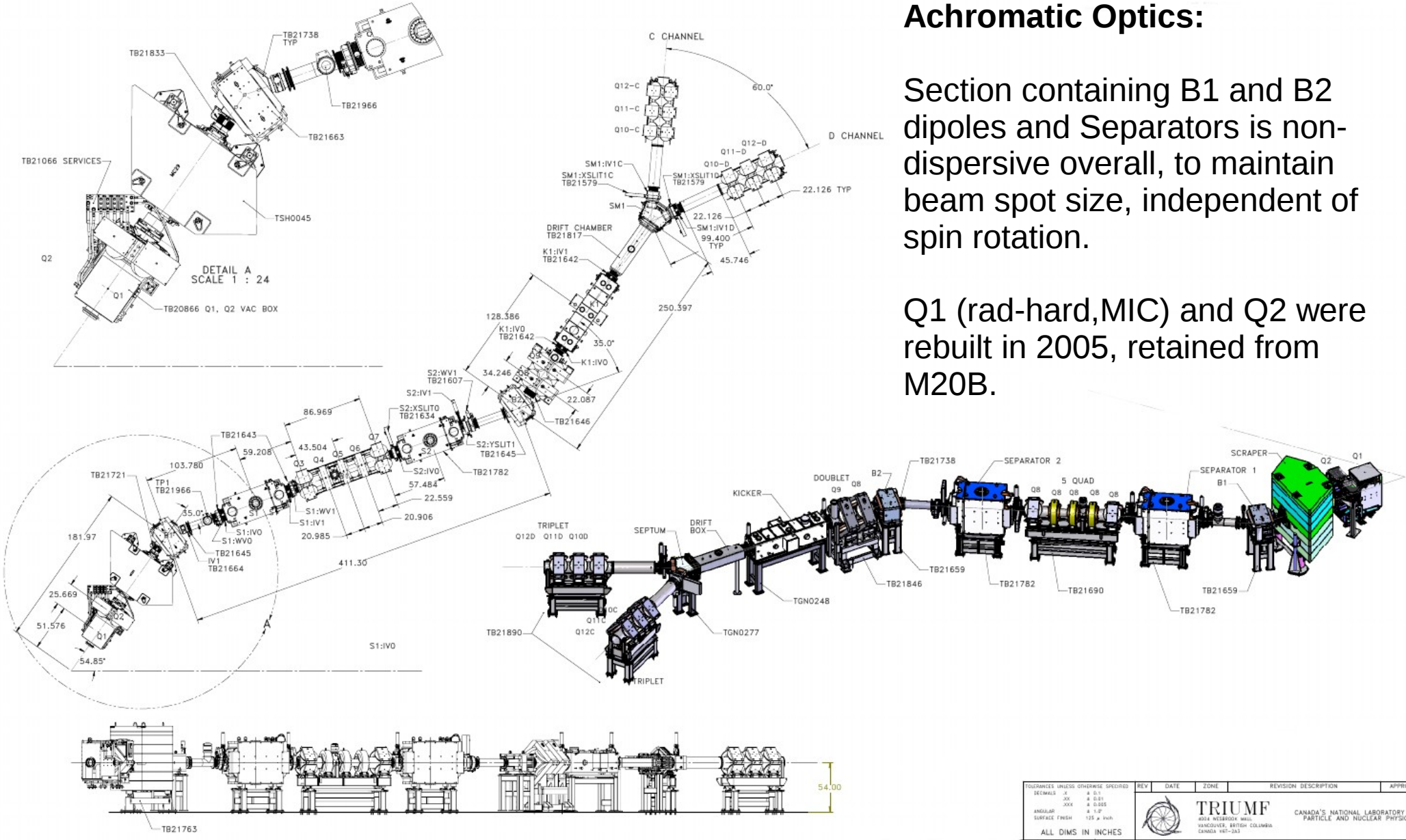
Green = +/- 4% ΔP/P

Emphasis on central luminosity rather than total rate.

Strong final focusing produces overall magnification <1 .
Three adjustable slits for controlling momentum bite (HF2) and rate (VF2, HF3)

10cm T2 target is longer than is useful. A shorter target would reduce fields and activation near T2. A design study on target shape optimization is required.

M20B optics design

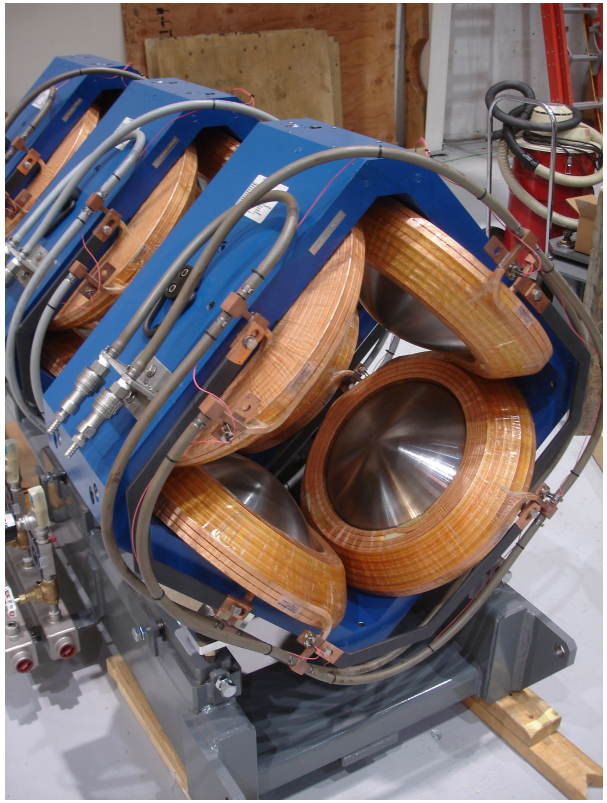


Achromatic Optics:

Section containing B1 and B2 dipoles and Separators is non-dispersive overall, to maintain beam spot size, independent of spin rotation.

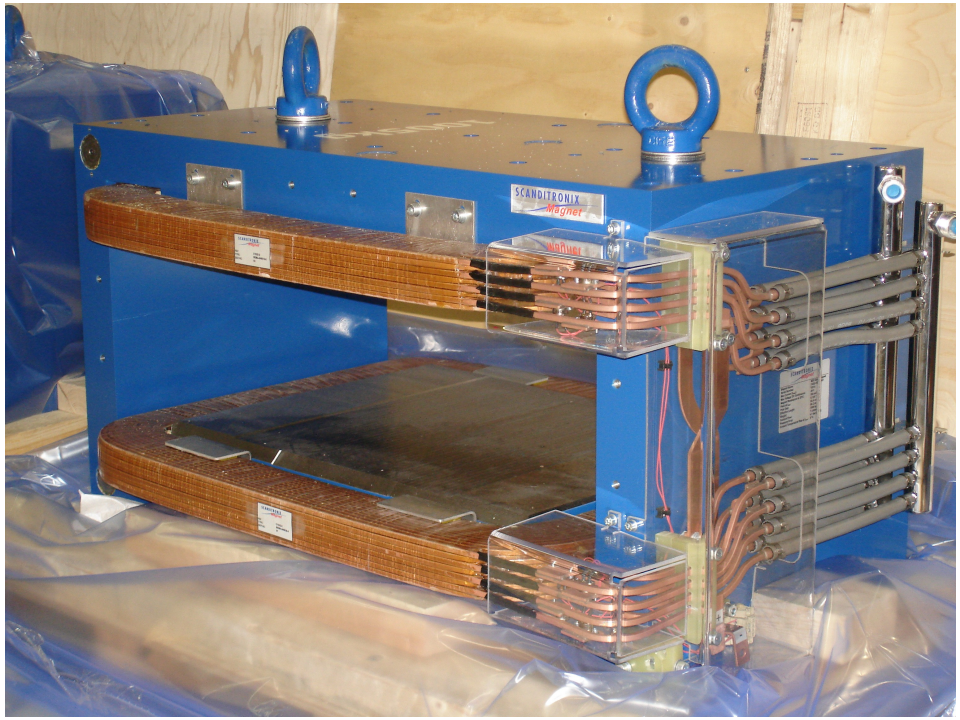
Q1 (rad-hard,MIC) and Q2 were rebuilt in 2005, retained from M20B.

New Hardware: magnets



8 new quadrupole magnets, made to an existing TRIUMF design (12Q12-1.5)

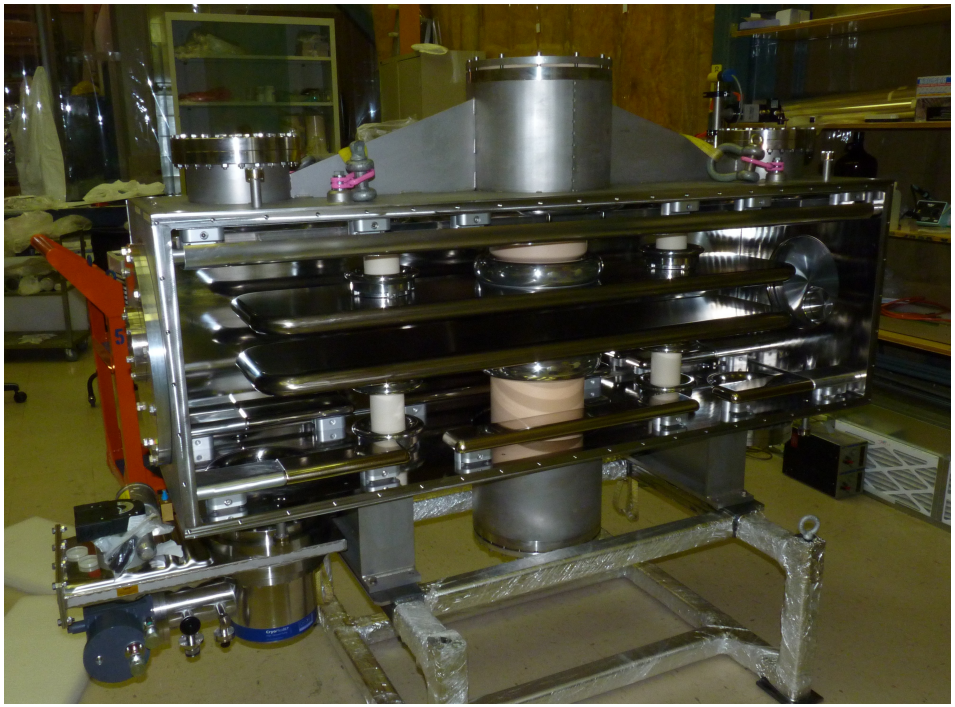
- 0.31m aperture
- 1.11T/m gradient @200A.
- effective length 0.322m
- nearly spherical (hyperboloid) poles
- 725kg
- CA$38k each



2 new dipole magnets designed, fabricated and mapped

- vertical gap 0.225m
- maximum field 0.125T
- effective length 0.600m
- 1008 kg
- CA$55k each

New Hardware: Spin rotators / separators

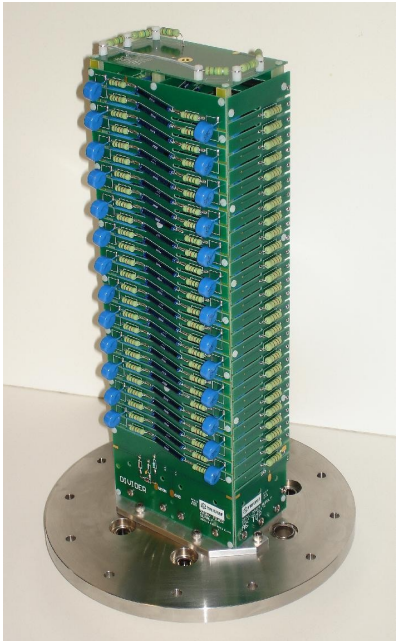


Separator Specifications:

Effective length (magnetic and electrostatic) : 1500mm

Electric Field:	Vertical, up to ±175kV / 80 mm
Good field volume	200mm W x 80mm H x 1200mm L
E, B field matching	Maximum deviation from on-axis trajectory : 4mm
Magnetic field	Horizontal, nominal 512 G, 640G maximum.
Magnet:	512G@150A, 11kW max., conventional water cooled conductor.
High voltage	HVPS's in 2 atm abs SF_6

Materials: Solid titanium electrodes, stainless steel vacuum box with aluminum liner behind anode, alumina ceramics.
Integrated compact HVPS avoids use of cables, additional feedthroughs.
Triple points (metal-insulator-vacuum junctions) located in low E-field.
Cost approx CA$0.55M each



New Hardware: Fast Kicker – Muon on Request

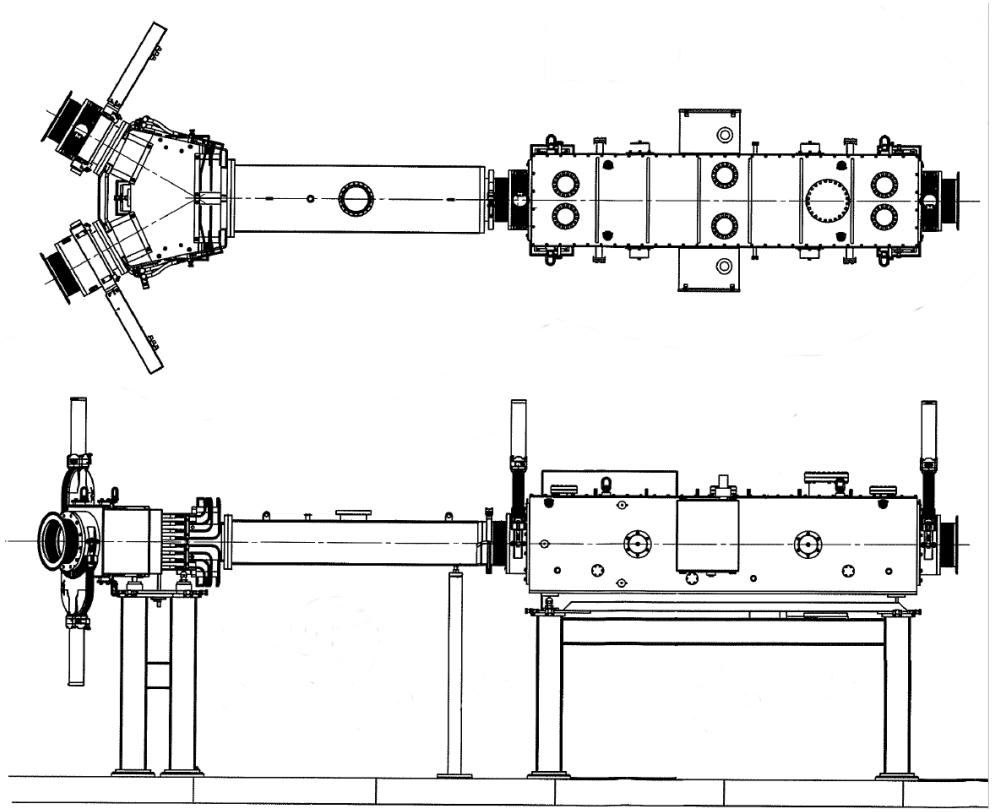
Driven by one of either C or D-leg experiment, the kicker will turn off the beam after one muon has arrived, suppressing uncorrelated backgrounds and enablng use of longer histograms.

Fast electrostatic kicker followed by DC thick septum magnet.

specifications:

Electric field : Horizontal, bipolar ±20kV / 15cm gap

Effective length:	2 m
Kick angle:	1.8°
Total bend	+/-30°
Total delay + Rise time:	200 ns
Minimum hold time:	300ns
Maximum hold time :	infinite
Maximum average switching rate	40KHz
Kicker + Magnet cost	CA$500k + $110k



The M20 kicker is currently in factory testing and debugging. A temporary DC magnet is currently in the beamline to produce the same bend, w/o switching.

New M20 Performance

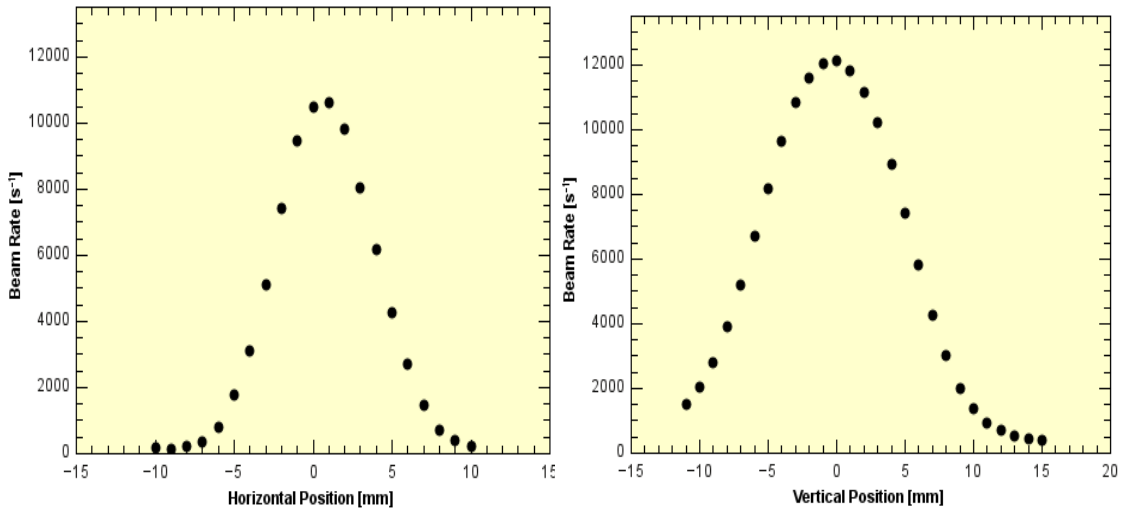
Tuned optimally for a sharp beam spot and rates suitable for time-differential μSR, M20 can deliver up to 110,000 $\mu^+ s^{-1}$ into a beam spot 12mm tall × 7.5mm wide FWHM, with 100μA of protons (CW) on target. This would usually be reduced to an optimal ~40,000 s^{-1} when acquiring typical 10μs histograms.

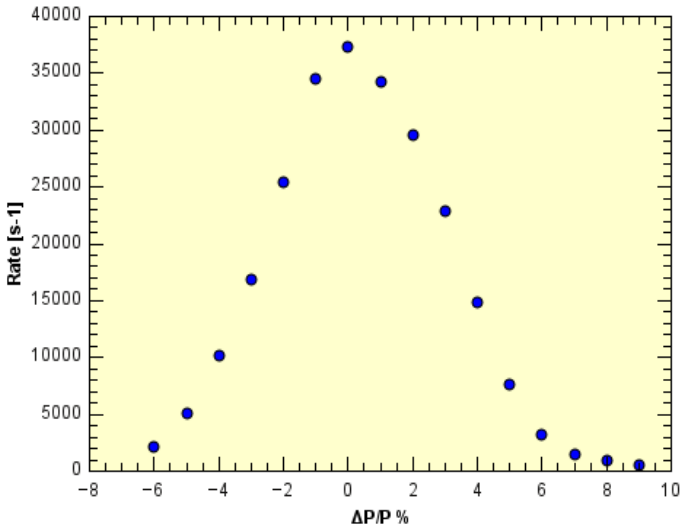
Avoiding use of collimation close to the spectrometer minimizes positron background.

Tuned for higher rates suited for integral-mode experiments, 230,000 – 500,000 can be delivered into a 15mm spot, at nominal proton current of 100 μA.

Separators are effective at removing positrons from less than 5 º spin rotation for longitudinal or zero field experiments. Up to 90 º spin rotation at full voltage ±175kV can be achieved.

Momentum acceptance of the beamline (following B1) at a typical Time-Differential tune is ΔP/P = +/-3% FWHM





Time-line for the project

Optics Designs	2006 – 2007
Beam line elements design	2008-9
Mechanical design	2008-10
Major elements P.O.s	July 2009
Demolition	Dec 2010 – Mar 2011
Magnets arrive	Oct 2010 (69 weeks ARO)
Services, controls, PS's etc	Aug 2011- March 2012
Separators arrive	March 2012
First beam w/o spin rotation	Aug 2012
First scheduled experiment	Oct 2012

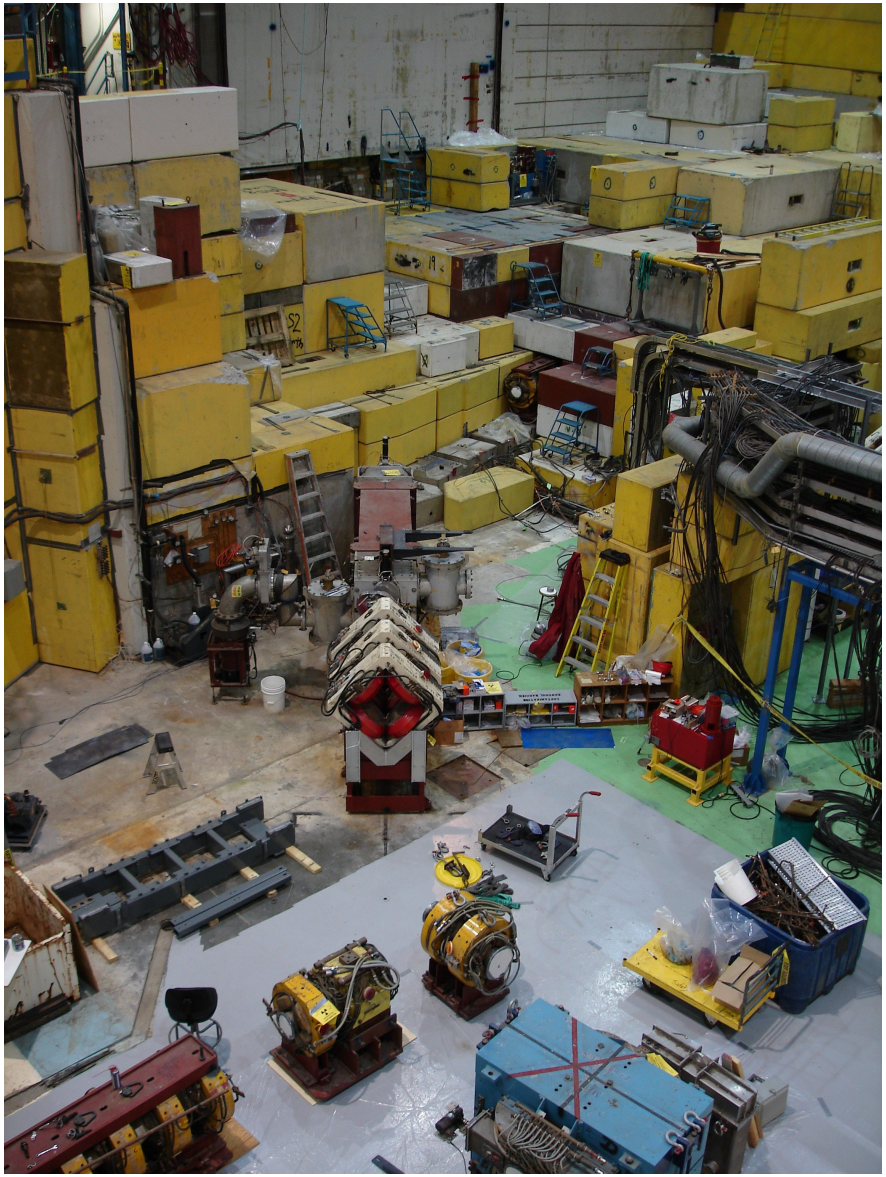
Total cost $6.024M (roughly ½ components and ½ manpower)

Project funded by :
Canadian Foundation for Innovation (CFI),
British Columbia Knowledge Development Fund
And TRIUMF

Old to New M20 In Pictures

Dec 8, 2010

Old to New M20 In Pictures



Jan 11, 2011

Old to New M20 In Pictures

Mar 14, 2011

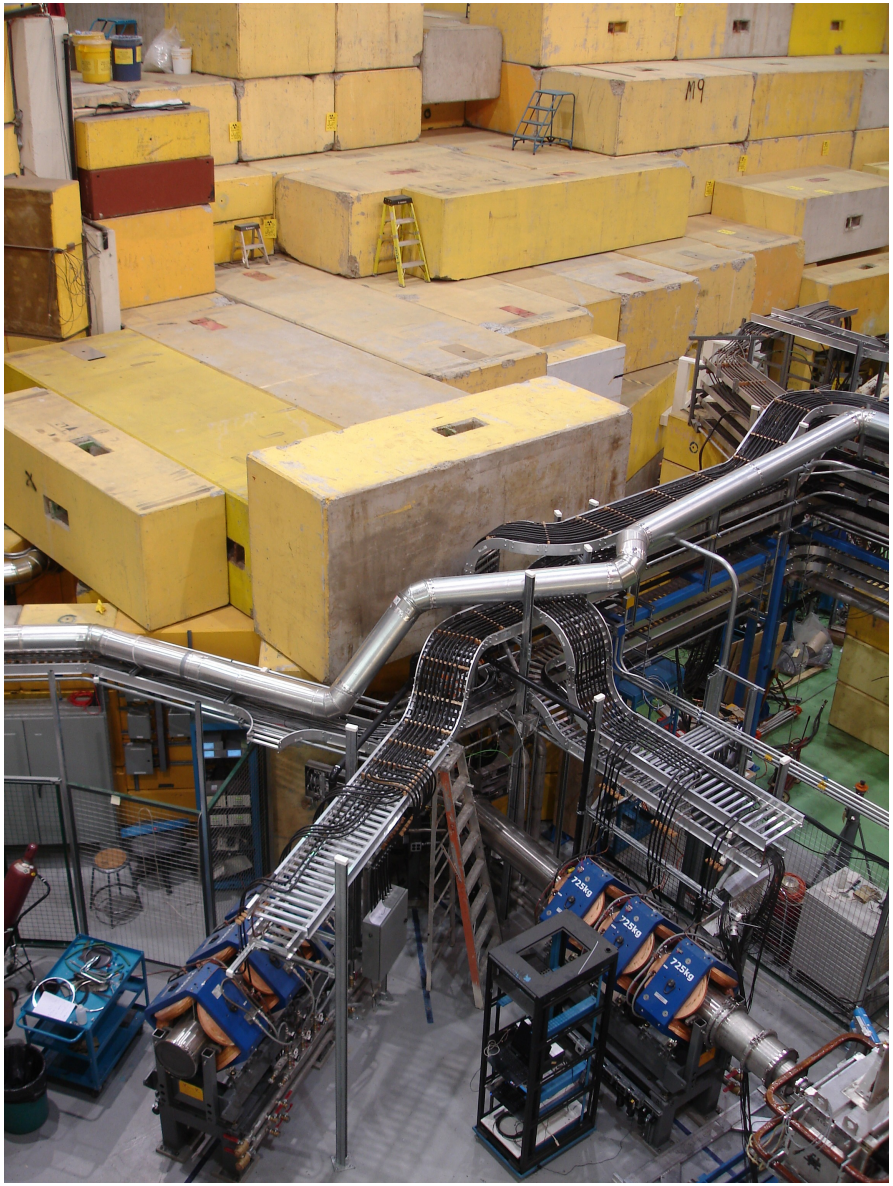
Old to New M20 In Pictures

March 7, 2012

Old to New M20 In Pictures

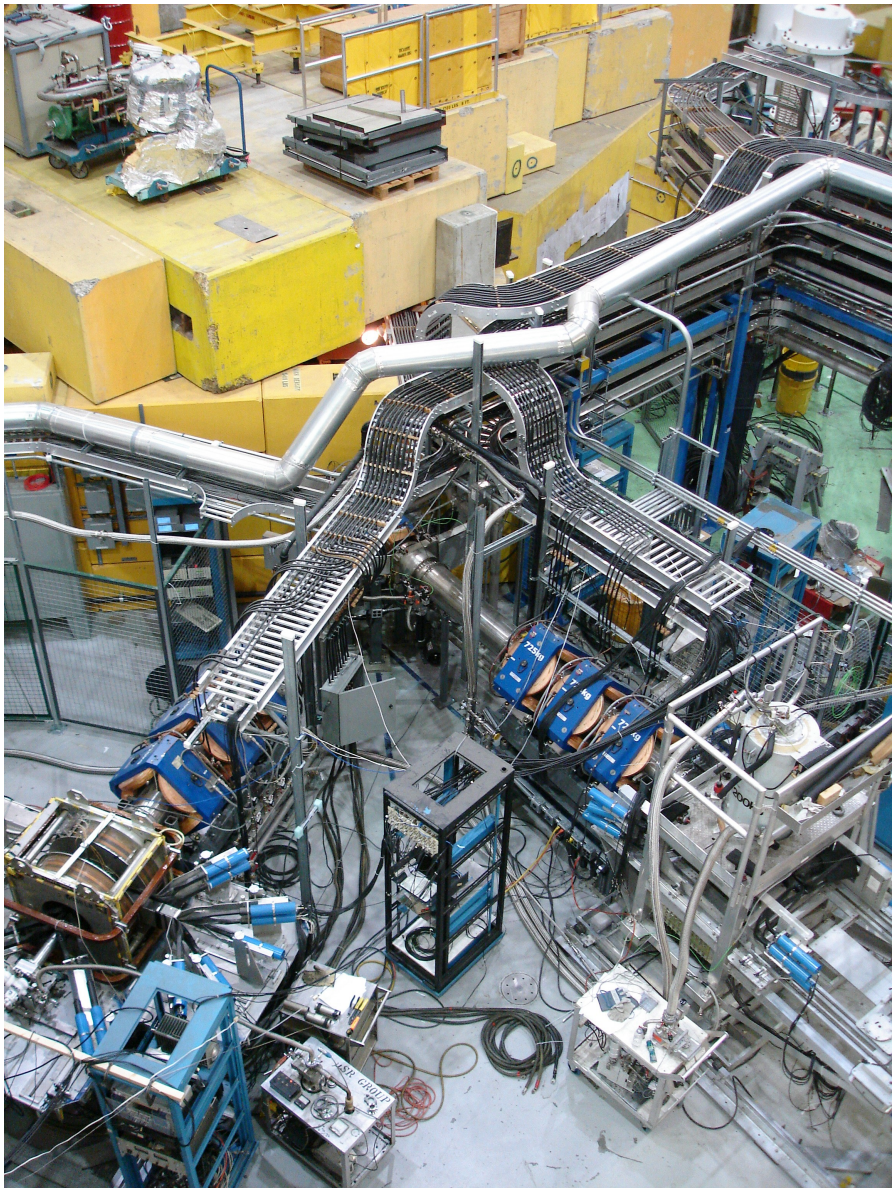
June 27, 2012

Old to New M20 In Pictures



Aug 15, 2012

Old to New M20 In Pictures



July 18, 2014

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